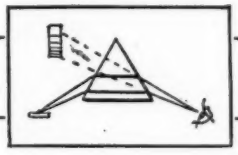
Journal of the

OPTICAL SOCIETY *of* AMERICA

VOLUME 23
No. 7



JULY
1933

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Published monthly
at Prince and Lemon Sts., Lancaster, Pa.
by the
AMERICAN INSTITUTE OF PHYSICS
Incorporated
11 East 38th Street, New York, N. Y.
FOR AND UNDER THE EDITORIAL SUPERVISION OF
THE OPTICAL SOCIETY OF AMERICA

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Journal of the
OPTICAL SOCIETY
of AMERICA

VOLUME 23 JULY, 1933 NUMBER 7

Photographic Plates for Use in Spectroscopy and Astronomy. III

C. E. KENNETH MEES, *Kodak Research Laboratories**

(Received March 21, 1933)

IN two former communications on this subject,[1] a description was given of the characteristics of plates developed especially for scientific work by the Research Laboratory of the Eastman Kodak Company, these plates being based on four distinct types of emulsion, which are shown in Table I.

TABLE I.

Type	Sensitivity	Contrast	Graininess
I.	High	Medium	Average
II.	Mod. high	Medium	Average
III.	Medium	High	Low
IV.	Low	Very high	Very low
V.	Low (when sensitized)	Very high	Negligible

To these four types we have now added type V, which when unsensitized is extremely slow—too slow to be of any use for ordinary scientific work—while its grain is much smaller than that of any other of the emulsions, the image appearing almost as a stain. The resolving power is naturally very high—higher than that of any other emulsion available. When this material is sensitized with a few of the special panchromatic sensitizings (*B*, *C*, *D* and *F*), it acquires appreciable speed, being almost as fast as the type IV emulsion. It is believed that the material may be useful in spectroscopic instruments whose dispersion is small, resolving power high, and intensity relatively high. The very high resolving power and freedom from graininess of the emulsion make it possible to get results corresponding to those which could be obtained on instruments of much higher dispersion.

In my previous papers, seven types of sensitizing for the visible spectrum were designated by the letters *B*, *C*, *D*, *F*, *G*, *H*, and *J*, and four types of sensitizing for the infrared by *N*, *K*, *P*, and *Q*. During the past year, a great deal of work has been done in an endeavor to improve these types, to fill gaps which experience has revealed, and to supply other materials which might have special uses.

It is now thought worth while to summarize the changes which have been made, so that the new developments may be known to astronomers and spectroscopists who might have use for them.

SENSITIZING FOR THE VISIBLE

Wedge spectrograms of the sensitizings now available are shown in the figures. These sensitizings can be applied to all types of emulsion with the exception of type V, which can be sensitized only as stated above.

The types *B*, *C*, *D*, and *F* sensitizings have been modified somewhat during the past year, the new

* Communication 487.

[1] C. E. Kenneth Mees, J. Opt. Soc. Am. **21**, 753 (1931); **22**, 204 (1932).

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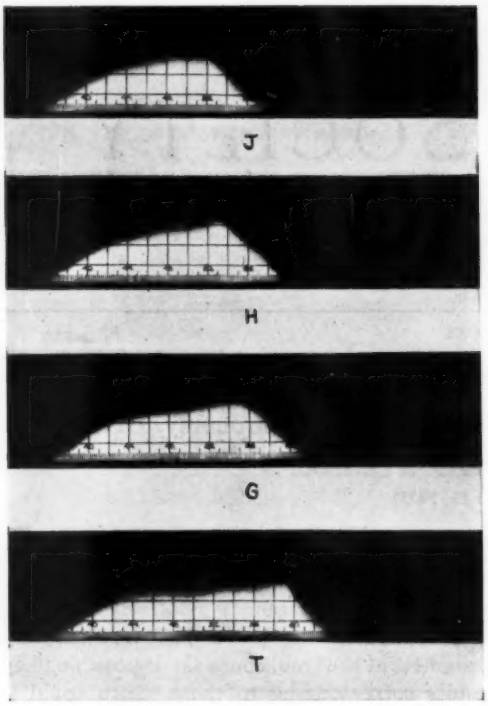

FIG. 1. Typical spectra of plates sensitized for the blue, green and yellow.

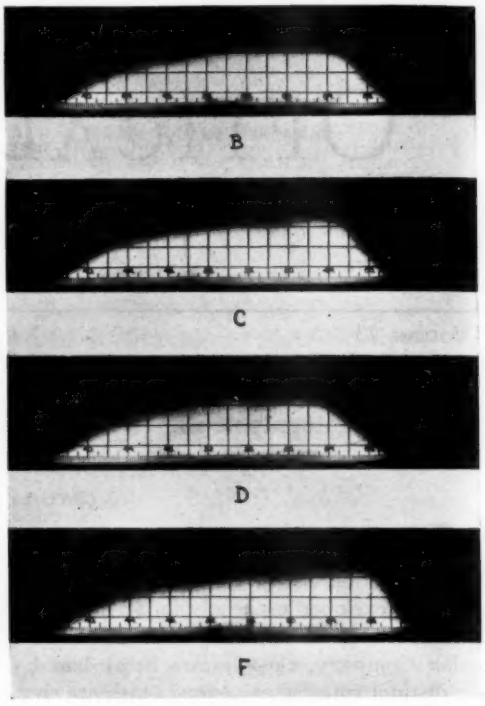

FIG. 2. Typical spectra of plates sensitized to the visible spectrum, including the red.

B sensitizing being slightly more sensitive in the red; the *C*, *D*, and *F*, slightly more sensitive in the green (Fig. 2). The *G* sensitizing remains unchanged, as does *H*, but the *J* sensitizing has been changed markedly. The sensitivity of the *J* type above λ5200 now diminishes rapidly, but the new sensitizing gives somewhat more even sensitiveness in the region between λ4600A and λ5200A (Fig. 1).

Three new sensitizings for special spectral regions have been added: One has a maximum of sensitivity at λ5900A and is therefore particularly suitable for the photography of faint spectra. It shows the *D* lines of sodium and is designated as the type *T* sensitizing. Another has a very high maximum at λ6900A; this is designated as type *S* (Fig. 3). The third has a maximum at λ7100A and gives high sensitivity from λ6800A to λ7400A; this is known as type *U*. It has also been found that a plate can be made which is sensitive throughout a very great spectral range from the ultraviolet to λ9000A in the infrared. The exposures required with this plate are greater than those necessary if separate plates are used for each spectral region, but the new long range plate, which is known as type *L*, is likely to be useful in preliminary surveys and for use with instruments of low dispersion.

SUGGESTIONS AS TO THE CHOICE OF SENSITIZING AND EMULSION TYPE

For *general spectroscopic work* at wave-lengths less than λ6100A, the type *D* sensitizing is recommended; from λ6000A to λ6800A, the type *F* sensitizing.

For general use with *reflecting telescopes*, the I-*C* plates (Wratten hypersensitive panchromatic) are very satisfactory provided that there is no objection to using panchromatic plates.

For *refracting telescopes*, astronomers who have made tests with a number of plates have selected chiefly the II-*B* plates (Wratten panchromatic), which with a No. 12 Wratten filter seem very satisfactory. The Wratten *M* plates (III-*B*) have

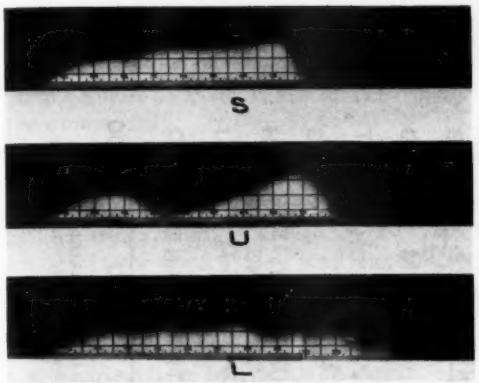

FIG. 3. Typical spectra of plates sensitized for the visible spectrum, including the extreme red.

the same sensitizing and are of higher contrast and lower speed.

For the *corona* and for spectra where *maximum sensitivity at λ5300A* is essential, the type *H* sensitizing is recommended;

For the *mercury green* line and the *auroral* line, type *G*;

For the *D* lines *of sodium*, type *T*;

For *H-alpha*, type *C* or type *F*.

SENSITIZING FOR THE INFRARED

Four types of sensitizing for the infrared were described in previous papers, designated as *N*, *K*, *P*, and *Q*. These have been continued and a new sensitizing, type *R*, has been added (see Fig. 4). Moreover, whereas formerly only slow emulsions, such as types III and IV, could be sensitized for the infrared, we have now succeeded in making type I emulsions which sensitize well for the infrared. These are of especial value with the *N* type sensitizing since type III emulsion does not sensitize well with the *N* sensitizer, while the new I-*N* plates have very good sensitivity. As a result of this work and of some increase in the contrast of type I, the type II emulsion seems to have little application.

The I-*R*, I-*P*, and I-*Q* emulsions have a sensitivity approximately three times that of the III-*R*, III-*P*, and III-*Q* plates.

The *R* sensitizing, which is now published for the first time, has been in use by several workers

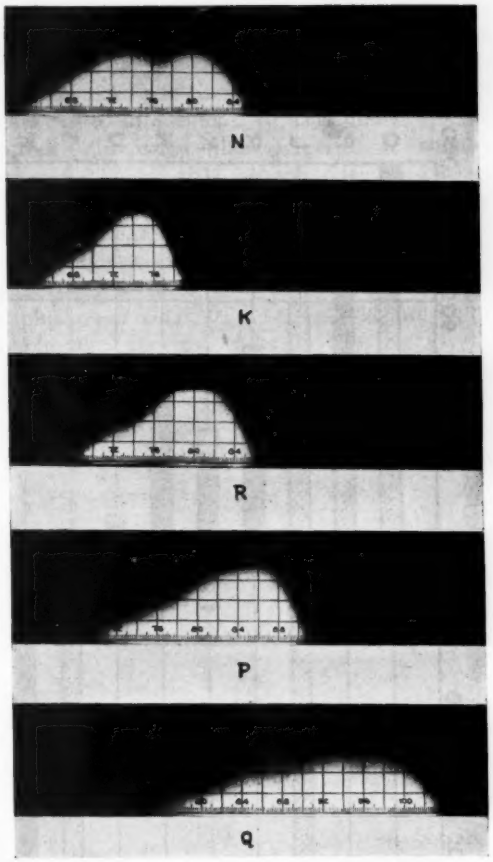

FIG. 4. Typical spectra of plates sensitized for the infrared. The plates have had exposures suitable for each, and prints therefore do not indicate the relative sensitivity.

during the past year and has proved extremely valuable, the region of high sensitiveness extending from λ7400A to λ8400A.

The *Q* type sensitizing with Xenocyanine has been improved, III-*Q* plates now being freer from fog and keeping well for some weeks at room temperature and almost indefinitely in a refrigerator. The new I-*Q* plates are extremely sensitive to the far infrared, their maximum being at approximately λ9800A.

For the infrared, therefore, the following recommendations are made:

For the region from λ6800A to λ8200A, I-*N* plates are recommended, but if the maximum sensitivity is required, I-*U* plates should be

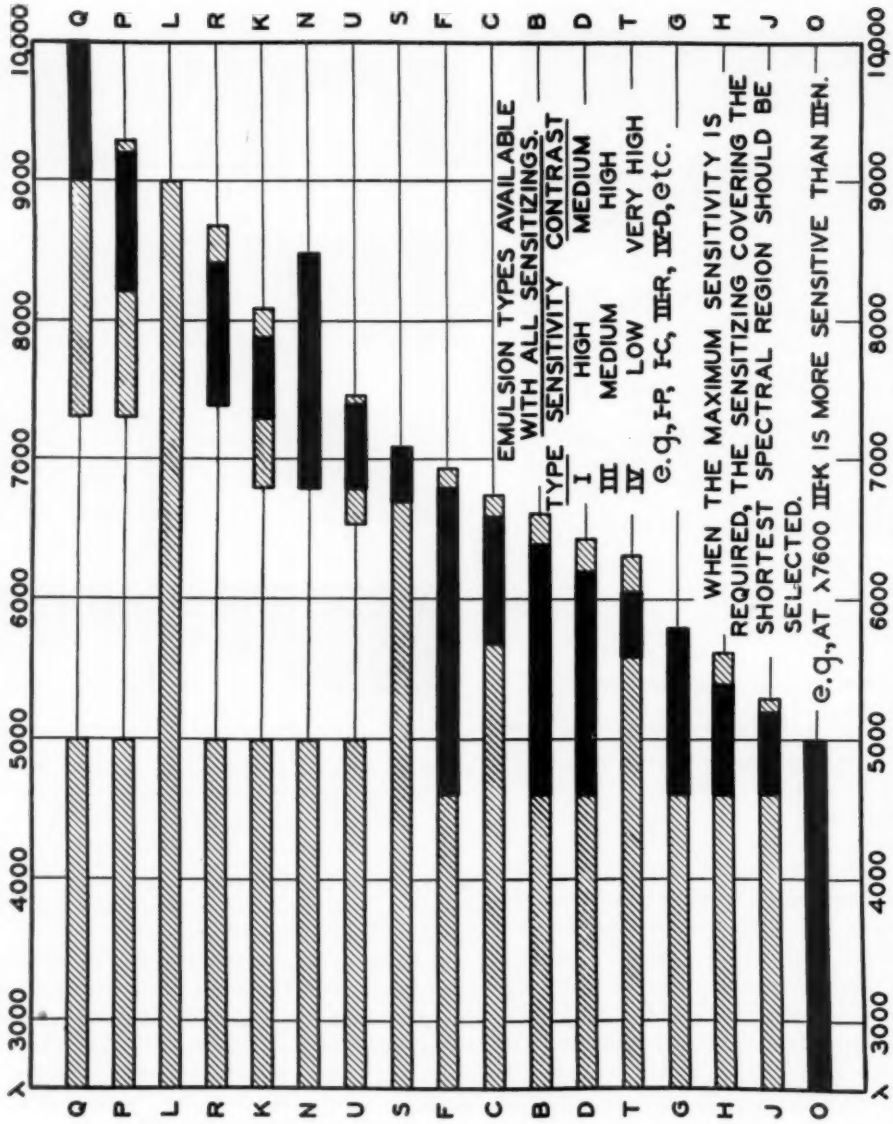

FIG. 5. Eastman Spectroscopic Plates. Diagram showing the spectral regions to which various types of plate are sensitive. The letters refer to sensitizing types. Cross-hatched areas show total sensitivity. Solid block areas show spectral regions for which type is especially valuable.

used from λ6800A to λ7300A; I-*K* plates should be used from λ7200A to λ7800A; and I-*R* plates, from λ7600A to λ8400A.

From λ8300A to λ9200A, I-*P* or III-*P* plates are recommended;

From λ9200A onwards, III-*Q* plates are recommended unless the greatest possible extension of the spectrum or the shortest possible exposures are required, in which case, I-*Q* plates are much faster though they tend more to fog and perhaps will not keep as well.

The ultraviolet spectroscopic plates referred to in the previous papers seem to be satisfactory, and no changes have been made in them.

The diagram of the spectrum shown in Fig. 5 summarizes the whole situation and shows the recommendations which the author makes for different spectral regions as a result of the correspondence which he has had during the past year. (An additional copy of this figure appears as a supplement to this issue of the journal.) In using this diagram, it should be remembered that where one sensitizing covers a shorter range of the spectrum, it is recorded because over that shorter range it enables shorter exposures to be given; e.g., the range from λ4800A to λ5200A can be photographed on *H*, *G*, *B*, *D*, *C*, or *F* plates, but *J* will enable the shortest exposure to be given. Similarly, the region from λ7800A to λ8200A can be photographed on *L*, *N*, or *P* plates, but the shortest exposure will be possible on *R* plates.

The Photometry of Solar Eclipse Phenomena

CLAYTON H. SHARP, S. MCK. GRAY, W. F. LITTLE AND H. J. ECKWEILER, *Electrical Testing Laboratories, New York, N. Y.*

(Received March 14, 1933)

The Electrical Testing Laboratories of New York desiring to supplement the work in the photometry of eclipse phenomena which it had done through three expeditions at the time of the 1925 eclipse, designed apparatus and methods and sent an expedition to Lancaster, New Hampshire to observe the eclipse of August, 1932. In preparing for this expedition features connected with the photometry of eclipse phenomena were considered anew and are discussed. The use of the term "brightness" with reference to the solar corona is criticized as misleading and not in accordance with photometric usage. The quantity to be measured is the illumination produced by the corona. Discussion is made of erroneous and misleading values for corona illumination which have been published and which refer to illumination produced not by the corona alone but by the corona together with a large area of sky and which have no especial scientific significance. Specially designed photometers are described for measuring the coronal light, the horizontal illumination and sky brightness. These have filters to give a color match in the photometric field as closely as the color to be encountered can be predicted. They have easily manipulated neutral screens to cover the range of intensities. The coronal photometer has an optical system whereby the field included is accurately defined and a "homemade" heliostat to keep the sun in position. There is also a photoelectric photometer for corona measurement consisting of a vacuum photoelectric cell with colored filters correcting its response to the eye sensitivity curve. This acts through an amplifier with an FP-54 tube and is fitted with an optical system for delimiting the field. Special recording arrangements are described. Cloudiness at Lancaster prevented any measurements of the corona light to be obtained. It was found that the total illumination on a horizontal plane at the time of totality was 0.35 footcandle.

PART I. GENERAL

UNDER the auspices of the Illuminating Engineering Society a concerted effort was made to obtain, through all available agencies, photometric data on the phenomena appearing at the time of the total solar eclipse of January 24th, 1925. The phenomena measured were: (1) The light of the solar corona. (2) The illumination on a horizontal plate exposed to the entire light of the sky including the sun. (3) The brightness of the sky at as large a number of points as could be observed during the limited time of totality.

Not less than eleven expeditions distributed along the line of totality in localities ranging from Hamilton, Ontario, to Montauk Point at the eastern end of Long Island took part, and at altitudes from 1540 feet above sea level to practically sea level.

Certain results were obtained among which may be cited the value of 0.24 footcandle as an average of the various measurements for the illumination on horizontal plane at time of totality and the value of 0.012 footcandle for the illumination due to the corona alone as obtained from visual photometric values and 0.017 footcandle as obtained from a photoelectric photometer with potassium cell. These matters have been fully reported in the Transactions of the Illuminating Engineering Society.[1]

The Electrical Testing Laboratories of New York (ETL) having contributed to the leadership of this movement and having participated through three separate expeditions, one at Mount Beacon, New York, one at Montauk Point, New York, and one at North Salem, New York, and having found the results less satisfactory than had been hoped for, largely on account of the impossibility of obtaining, before the eclipse, a sufficient idea of what the conditions would be at the time of the eclipse (as, for example, the color of the light of the corona so that adjustments could be made to permit photometric measurements of the desired degree of accuracy), and also because of the extremely adverse weather conditions under which the measurements had to be made, deemed that it would be a useful contribution to science to make an attempt to repeat the work in

[1] IES Trans. 20, 565 (1925).

connection with the eclipse of August 31, 1932. This gave an opportunity to utilize the experience gained in 1925 and to make much more perfect preparations and instrumental equipment than had been possible on the earlier occasion.

The apparatus constructed for the purpose of these measurements had a number of novel features. It is believed that it was well thought out and well built for the special apparatus at hand. In the hope that this work may not be entirely lost but may be of value to others in this or in some different connection it is described herewith.

Discussion of recent published data on coronal light

In view of the recent publication of certain papers on photometric measurement of eclipses in which statements and data of a possibly misleading character are put forth, it seems opportune to make a brief review of certain aspects of the subject. This review will appear to a photometrist to be of such an elementary character that the question arises why it should be made at all. Evidently, however, there are workers in this field who, no matter what their competency may be in their own particular lines, are not familiar with the progress which has been made in the science and art of photometry of recent years and have gone astray when confronted with the complexities involved in the photometry of eclipses. It is desirable that these matters should not be allowed to remain on the record uncorrected.

Let us first consider a question of terminology. Some astronomers have referred to the measurements made of the light of the solar corona as measurements of the "brightness" of the corona. The term brightness as used in ordinary terrestrial photometry has a perfectly definite meaning. It refers to the luminous appearance of a surface (or apparent surface) when looked at. Thus, the brightness of an illuminated surface or of the sky or of the solar corona may be measured and the values compared but the brightness figure gives no information as to the amount or intensity of the light which, coming from the surface, reaches the observer, unless the apparent extent of the surface also is stated. The brightness of the solar corona is quite different in different regions and might well be made the object of study. The quantity which has been measured photometrically and sometimes called brightness is not brightness but is illumination produced on the earth's surface—quite a different thing.

From the above point of view brightness as applied to the fixed stars is a meaningless term. Historically, of course, it has justification and can in itself scarcely cause confusion. When speaking of the brightness of celestial bodies of measurable apparent extension, however, an entirely unnecessary and inexcusable confusion is introduced if the term is used with any other meaning than the one which is established in the terminology of photometry.[2]

The illumination produced by the corona being the quantity to be measured, the diffused illumination from the sky is, to the extent to which it cannot be excluded from entrance into the photometer, a disturbing factor. The obvious procedure is to allow the luminous flux, from as small a region of the sky as possible, to fall upon the photometric test plate so that the entire effective light area of the corona as far as it is known shall be included. The illumination of the test plate will then be due first, to the corona and second, to the patch of sky observed. The proportion of this illumination which is due to the sky can be approximately determined by measurement of the illumination produced by a patch of sky of equal area near the sun but outside the radius of the corona.

The brightness of the sky at the time of total solar eclipse is by no means negligible. None but the more prominent stars are visible. Measurements made at the time of the 1925 eclipse gave values for sky brightness at the zenith during totality of between 0.1 and 0.2 millilambert, while near the horizon values as high as 1 millilambert were observed. The average for the entire hemisphere was over rather than under 0.2 millilambert. In other words, the average brightness

[2] If the astronomers had adopted the terminology suggested by St. Paul, when he said "One star differeth from another star in glory," (δοξα), this conflict would not have arisen. As it is, there is need for a term to designate the effect produced on the eye by a punctiform source of light of no apparent area. At the Cambridge meeting of the International Commission on Illumination Professor Fabry on behalf of the French National Committee proposed the adoption of a new term *Eclat Stellaire*. It is to be hoped that this or some more suitable term may come into use.

of the sky was comparable to that of a white surface about 2¼ feet distant from a standard candle, while the maximum brightness corresponded to that of a white surface only one foot from the candle. The value of 0.24 footcandle for the illumination on a horizontal test plate corroborated these results. The brightness (specific intensity) of the corona was much greater than the brightness of the sky but its illuminating effect on the surface of the earth was only about one-twentieth of the illuminating effect of the hemisphere of sky.

The reason for pointing out these matters is that Professor Stetson[3] on repeated occasions has published results purporting to give the brightness of the corona which really give values for the illumination on a diffusing photometric test plate unscreened from all side light and placed normally to the rays from the sun.

The values given are, for the Sumatra eclipse, 0.138 footcandle, for the Malaya 1929 eclipse, 0.15 footcandle and for the Niuafou 1930 eclipse, 0.378 footcandle. It is to be noted that in 1930 a considerable amount of haze and cirrus clouds during totality increased the brightness of the surrounding sky. These figures should be compared with the figure of 0.24 footcandle for the *total* illumination on a horizontal test plate at the time of the 1925 eclipse, with which a reasonable degree of accordance was to be expected. In connection with the Sumatra eclipse a determination of brightness by a photographic method is reported, the method being one which should give the illumination due to the corona alone. The result was "a corresponding photovisual brightness of the corona of 0.015 footcandle." This is about 1/10th the value found with a photometer with an unscreened test plate, and is in good agreement with other measurements made of the illumination produced by the corona alone.[4]

[3] See Stetson, Coblentz, Arnold, Spurr, Astrophys. J. **61**, 65 (1927), *Investigation of the Corona at the Sumatra Eclipse of January 14, 1926.* Also S. A. Johnson, Astrophys. J. **74**, 122 (1931), *The Measurements of Corona Brightness at the Total Solar Eclipses, May 9th, 1929, October 21, 1929.* Harlan T. Stetson, J. Opt. Soc. Am. **21**, 144 (1931), *On the Use of the Macbeth Illuminometer in the Measurement of the Brightness of the Solar Corona.*

[4] It is to be regretted, however, that in reducing footcandles to meter candles Professor Stetson moved his decimal point in the wrong direction and hence came out with an answer which is 100 times too small.

There can be no objection to anyone measuring the normal illumination on a completely exposed test plate at the time of totality if he is convinced of the utility of so doing. Trouble, however, may ensue when the results of such measurement are seriously put forward as indicative of the amount of light which the corona is giving. But, apparently Professor Stetson does just that, on the assumption that the sky light is whole or chiefly scattered corona light. This assumption needs to be examined. The ratio of values obtained visually, unscreened and photographically for the Sumatra eclipse was about 10 to 1. The difference is attributed by Professor Stetson to the diffused light of the sky. The question at once arises; is this ratio in general agreement with the ratio in the parallel case of illumination by sky plus sun to that of the sun alone? The answer is that it is many times too large. For instance, data on pages 594 and 595 of the account of the 1925 eclipse show that at an altitude of 22 degrees the sun gave a direct illumination on a screened normal test plate of 14,000 footcandles on Mount Beacon. At the same time the horizontal illumination on an unscreened test plate was 7500 footcandles. Multiplying 14,000 by the sine of 22 degrees gives the horizontal component of direct sun illumination as 5250 footcandles. This leaves a difference of 1750 footcandles as the contribution of the diffused light. In other words, the ratio was not 10 to 1 but ¼ to 1. Further, on page 602, data are given for measurements made on the full moon which show that the diffused light contributed about ⅛th of the total illumination. All this is evidence which indicates clearly that the high sky brightness observed during totality and the high values for illumination obtained with an unscreened test plate cannot possibly be due in any considerable part to diffused coronal light.

This excessive amount of diffused light must originate chiefly in those regions of the atmosphere outside of the circle of totality. This was indicated in the 1925 eclipse by the presence of an extremely bright zone encircling the horizon, having, as noted above, values which were as high as one millilambert. This could not possibly be due to the corona. A similar effect was found in 1932, as shown further on in this article. The amount of such diffused light must depend upon the atmospheric conditions such as suspended

moisture, dust and cloudiness. (Note the high value obtained for the 1930 eclipse where cirrus clouds were present.) It would depend also to some extent on the character of the surface of the earth. Undoubtedly light reflected from the snow and reflected from atmospheric particles raised the value for the horizontal illumination observed for the 1925 eclipse. In measuring normal illumination as Professor Stetson did, the light received by the test plate, if entirely unobstructed, included light reflected from land or water as well as from sky. From these considerations it appears that the figures given by Professor Stetson as photometric determinations of the brightness of the corona really give measurements of illumination produced by the corona and by the sky in which the latter factor is the greatly predominating one. Since this factor depended on conditions which were quite independent of the corona, the measurements are valueless as far as giving any indication of intensity of coronal light alone is concerned. Any variations in coronal light from eclipse to eclipse are even more completely obscured.

Operations at Lancaster

The work was done on the Fair Grounds at Lancaster, New Hampshire. The apparatus was of a sufficiently portable character so that most of it could be transported by automobiles and set up in a few hours. The exact field of operation was selected and the instruments set up and checked on August 29th and 30th by Messrs. Sharp, Little and Eckweiler together with Miss Horn of ETL and Mrs. Little.[5] After checking and intercomparing instruments on August 30th the apparatus was covered with oilcloth and left in the care of a watchman overnight. On the morning of August 31st the party was augmented by Messrs. Gray and Chick and Misses Bell, Staats and Wallace of ETL. The checks and intercomparisons were repeated and a rehearsal was held, there being an ample trained force to handle adequately each detail of the work.

The weather which was partly cloudy on the morning of August 31st became worse as the day went on and although a last glimpse of the disappearing sun was caught in a partial opening of the clouds, the corona itself was entirely invisible. Nevertheless measurements of horizontal illumination were made and a curve shown in Fig. 1 gives the result. These results have no particular significance except to show the typical eclipse illumination curve and to give a minimum value of 0.35 footcandle which may be characteristic of the illumination at the time of total eclipse on a heavily clouded day in summer. Certain measurements of the sky brightness also were made and are recorded in Table I.

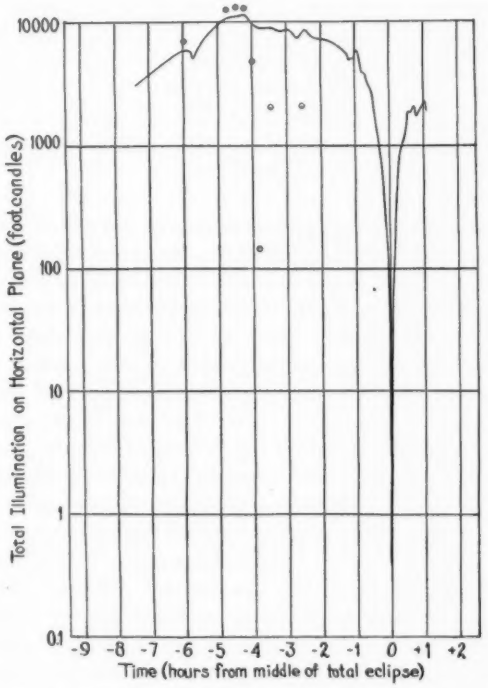

FIG. 1. Horizontal illumination throughout the day and normal illumination from the sun, August 31, 1932. Curves, horizontal illumination. Circle-dots, normal illumination from the sun.

PART II. OPTICAL PHOTOMETERS

(In charge of William F. Little)

In designing photometers for the ETL eclipse expedition of 1932 certain fundamentals were kept in view which, while not overlooked in the case of the 1925 eclipse, yet were at that time less perfectly appreciated. The main point outside of providing for the necessary color correction to enable photometric matches to be made with

[5] The necessary current supply was obtained from rented automobile batteries.

TABLE I. *Sky brightness.*

Time	Location	Millilamberts
3:26:56	Direction of corona	0.79
	At zenith	0.9
	At an elevation of 30° north	0.4
	At an elevation of 30° east	0.27
	At an elevation of 30° south	0.41
	At an elevation of 30° west	9.0
	At an elevation of 30° west	1.42
	Direction of corona	0.48
3:28	Horizon east	0.53
	Horizon north	6.3
	Horizon west	6.3
	Horizon south	10.7
	Clouds west horizon	1.7
	Clouds north horizon	1.9
	Clouds east horizon	1.2
	Clouds south horizon	1.1

Noteworthy is the band of high brightness near the horizon toward the west and south.

accuracy was to make such arrangements that the necessary accuracy and freedom from mistakes could be achieved under the conditions of rapid working and rapidly changing values which were to be encountered near and during the period of totality. This required the use of direct reading scales at all times and, to avoid complexity, the use of a minimum number of light absorbing filters which would need to be changed during this critical period. No commercial photometer meets these requirements in an adequate manner and so the plan outlined below was adopted.

The requirement of direct reading involved a scale range of slightly greater than 100 to 1 and hence a long travel of the comparison lamp. This was provided for by adapting a Macbeth illuminometer head to one end of a tube 20 inches long and 2½ inches in diameter with a special carriage and a rack and pinion movement similar to that on the ordinary Macbeth illuminometer. The color match was secured with sufficient approximation by means of a blue tinted glass in front of the comparison lamp. This in turn required a 15-candlepower automobile lamp as a comparison lamp. This lamp was carefully selected to see that its filament and the image of the filament reflected from the spherical portion of the bulb were coincident. Otherwise the scale computed according to the inverse square law would have been inaccurate. The scale engraved on the rack read directly from 4.8 to 600 footcandles. A neutral filter on the outside (transmission approximately 0.01) served to extend the range well above the maximum which might be expected. Two neutral filters on the comparison lamp side (transmissions approximately 0.01 and 0.0009) enabled intensities below that of the lowest expected value to be covered. For use with absorbing filters auxiliary scales of paper were provided and an arrangement made (shown in Fig. 2) such that when a filter was introduced the proper scale came into place to be read and these scales were, like the one engraved on the rack, direct reading scales. In this way all illumination values from 0.005 up to 600 footcandles were read directly without applying a factor or shifting the decimal point.[6] A small flashlight lamp mounted behind the indicator enabled the scales to be read at times when the natural illumination was insufficient.

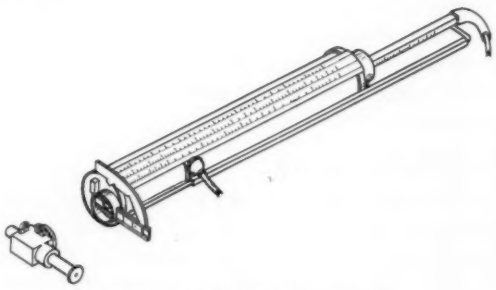

FIG. 2. Special photometer.

The instrument for measuring horizontal illumination was fitted with a compensating test plate which gives a good accuracy of integration of the light over an entire hemisphere in accordance with the theoretical cosine law. The eyepiece was fitted with one-half of a hollow rubber ball with a hole cut in it fitting over the tube and serving as a shield for the eye of the observer. The instrument was mounted on a heavy tripod.

The instrument intended for the measurement of the direct light of the sun and corona was fitted with an optical system consisting of two lenses and a stop so arranged that the outer lens focussed the sun on the plane of the stop and the inner lens focussed the outer lens on the test plate of the photometer. The aperture of the stop was such

[6] As a matter of convenience a third filter was added to shorten the range covered by each of the other two.

that the light of a patch of three angular degrees of the heavens illuminated the test plate. This lens system is identical in principle with the one described further on in this article and illustrated in Fig. 11. The value of three angular degrees was selected as covering with certainty all parts of the corona which are bright enough to be seen against the background of the sky at time of totality and at the same time excluding as much of the light of the sky as possible. This instrument was mounted parallel to the earth's axis pointing toward the south and looking at the mirror of a heliostat whereby the sun's image was kept central in the tube. The mounting of the photometer was a stiff angle iron frame which could be transported knocked-down and which was extended upward and served as a framework for a housing of compo-board, shielding the eyes of the observer from outside light. This was quite important because of the relative faintness of the photometric field at time of totality.

The heliostat Fig. 3 was built for the purpose around one of the powerful clock mechanisms which are used in the curve-drawing instruments of the Bristol Instrument Company. The mirror was supported in a fork, turned on a ballbearing, and was geared to the hour spindle of the clock. The mechanism was mounted on a heavy adjustable tripod with levelling screws and a sector to set the mirror for latitude. This made a very satisfactory and inexpensive form of heliostat.

FIG. 3. Heliostat.

In addition there was a Macbeth illuminometer equipped with a lens system adapting it to read the brightness of a patch of the sky slightly less than one degree in diameter. This illuminometer was mounted on a motion picture camera tripod equipped with wormscrew adjustments so that it could be quickly and accurately aimed in any direction. The primary purpose of this instrument was to measure the brightness of the sky at a point as close as might be to the corona so that a value for the correction to be applied to the other instrument for the diffused light of the sky could be determined. In addition, the brightness in various parts of the sky could be quickly taken by releasing the worm mechanism.

As a further precaution against gross errors, a footcandle meter was constructed having a scale 30 inches long and using a 32-candlepower blue bulb automobile headlight lamp as a comparison lamp. The maximum reading of this instrument was about 1200 footcandles and the minimum considerably less than 1/10th footcandle. The method of taking readings on this instrument was to put a lead pencil mark on the scale every time that time was called.

The photometric equipment above described was finished well in advance of August 31st and was carefully calibrated in the laboratory. The illumination photometer was calibrated in the usual way by using a standard lamp at a known distance from the test plate. The corona photometer was calibrated by using a high candlepower standard lamp at a rather great known distance with its light reflected to the photometer by the heliostat mirror. The small brightness photometer was calibrated in four ways. (1) To read illumination with compensating reflecting test plate. (2) To read illumination with a transmitting test plate with a restricted field. (3) To read brightness of a small field with the lens attachment. (4) To read brightness of a larger field without the lens attachment.

These instruments were checked on repeated occasions during daylight and twilight hours both on the roof of the laboratory and in the country where an unobstructed horizon was available. The trials indicated that measurements could be made and recorded at intervals as short as two

seconds. After the instruments had been set up on the Fair Grounds at Lancaster the following intercomparisons were made.

(1) The illumination photometer and the corona photometer were intercompared by turning the illumination photometer directly toward the sun and excluding the major part of the sky light by means of a black velvet-lined tube over the test plate. Under these circumstances the instruments read the same values for illumination.

(2) The brightness photometer and the illumination photometer were intercompared by observing the illumination on horizontal test plates and making simultaneous readings. The lens tube was removed from the brightness photometer.

(3) The brightness photometer and the corona photometer were intercompared by affixing to the brightness photometer a transmitting test plate placed at the bottom of a velvet tube, the whole arrangement being directed toward the sun and simultaneous measurements of direct sun illumination being made with the corona photometer.

A further check on the accuracy of the brightness photometer was obtained through the fact that the reflection factor of the reflecting test plate having been determined, the illumination values obtained by it could be converted to brightness values. On the day before and on the day of the eclipse, such intercomparisons as these were made and the instruments were found to be in accordance with each other.

The heliostat was mounted in brass mounting plates attached to a heavy flat stone slab. The slab was carefully levelled in position and the meridian was found as follows:—A curve showing the azimuth of the sun as a function of the time for Lancaster was prepared in advance and a plumbbob was hung with its line at the center of a large protractor. From the position of the shadow of the line and from the time, which was furnished through the courtesy of the Mount Wilson Observatory party, who were located on the same grounds, the meridian was located and was indicated by stakes driven in the ground North and South of the heliostat.

Views of the photometric apparatus in the field are given in Figs. 4 and 5.

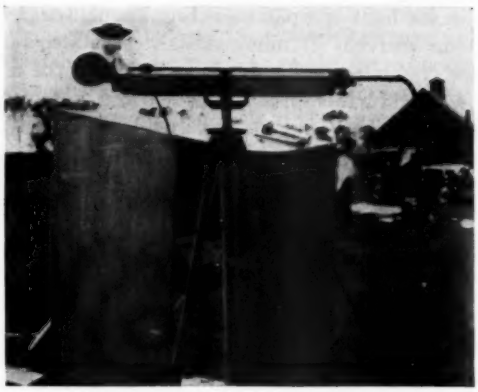

FIG. 4. Photometric apparatus in the field.

FIG. 5. Photometric apparatus in the field.

PART III. THE PHOTOELECTRIC PHOTOMETER
(In charge of Messrs. Gray and Eckweiler)

The photoelectric photometer was designed for measuring the illumination produced by the sun and by the corona at time of totality on a plate placed normal to the rays. Photoelectric cells have been used for this purpose on a number of previous occasions but, it is believed, always without any attempt made to adjust the response of the cell to correspond to the response of the normal human eye.

In previous work a potassium cell has generally been used as being the most available for the purpose in spite of the fact that its response uncorrected, overemphasizes bluish light and underemphasizes reddish light. The comparability of results of measurements of different eclipses de-

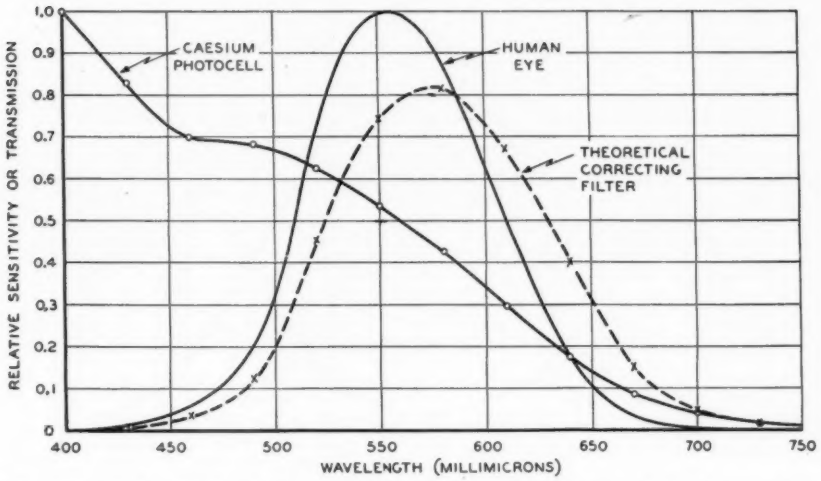

FIG. 6. Spectral sensitivity of human eye, of caesium photo-cell and transmission of correcting filter.

pends on a reliance on the constancy of the color response of a given cell, which is a somewhat uncertain matter, or on the accuracy of such corrections for color effect as may be made, which at best, are none too reliable.

The progress which has been made since 1925 in the production of photoelectric cells, notably in increases in sensitivity and in the distribution of the sensitivity throughout the spectrum, has rendered it possible to obtain photoelectric cells of such characteristics that by the use of selectively absorbing filters their response at all wave-lengths is rendered proportional to the relative visibility of the light at those wave-lengths. Evidently, a cell so corrected will give true photometric values irrespective of the color of the light. Hence, its indications can be directly compared with those obtained by visual photometers when the same primary photometric standard is used for standardizing them and thus a most valuable criterion for the accuracy of both can be established.

Correction of photoelectric cell response to eye sensitivity

The method employed was as follows:—The photoelectric cell of the PJ14 caesium coated vacuum type made by the Research Laboratory of the General Electric Company was selected. Its equal energy response curve was obtained with a monochromator, and a thermopile. This is given in Fig. 6 which also shows the visibility curve of the eye and a curve obtained by computation from the other two showing the transmission of a correcting filter which would serve to give to the combination of filter and photo-cell a response in accordance with the visibility curve. No filter commercially available corresponding to these requirements was known by us and hence recourse was had to a piecemeal correction of the different portions of the photo-cell curve by a plurality of filters. To cut off the excess in the short wave-lengths a certain piece of amber glass was found to be satisfactory. To cut off the excess in the red end of the spectrum a copper chloride solution was indicated. These two together would bring the response much closer to the required response, but some procedure would be required to make the final closer approximation.

As a result of an investigation of copper chloride solutions, using Beer's law as a guide, it was found that an 8 mm thickness of a 2.76 percent solution best fulfilled the purpose. The amber glass and the copper chloride solution placed behind one another gave a transmission curve shown in Fig. 7.

No commercial filter was found which would close the gap between this curve and the visibility curve, hence recourse was had to a procedure which has never been published but which has long been in use at the Electrical Testing Laboratories for the approximate color correction of

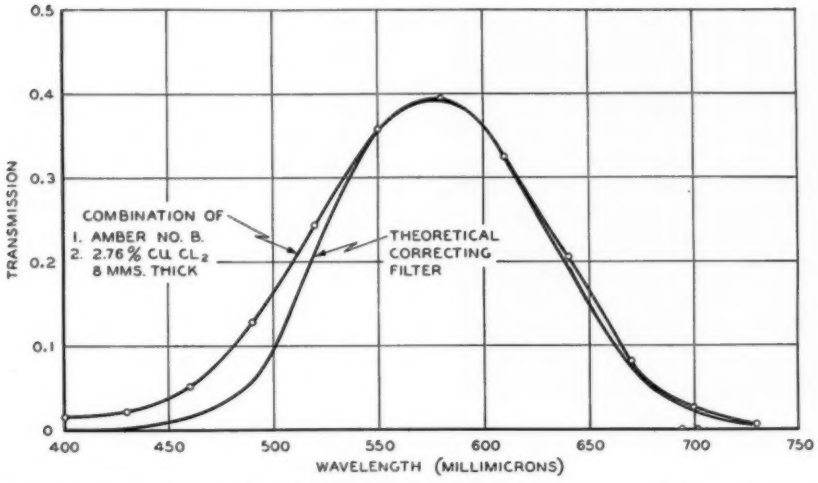

FIG. 7. Transmission of theoretical correcting filter and of first practical combination.

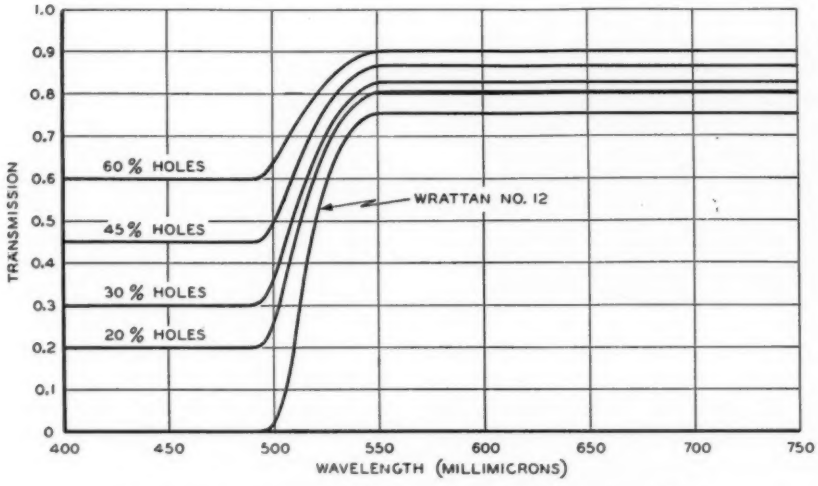

FIG. 8. Family of filters obtained by perforating Wrattan filter No. 12.

photoelectric photometers. This consists in taking a gelatine or celluloid filter which overcorrects and reducing the amount of its coloration to any required degree by boring holes uniformly distributed over its entire surface until the desired result is attained. The effect evidently is that of a dilution of the color transmitted and the degree of dilution depends upon the ratio of the holes to the entire area. The transmission at any wavelength is given by the expression $t_\lambda' = r + (1-r)t_\lambda$ in which "r" is the above ratio and "t_λ" is the transmission of the unperforated filter.

Wratten filter No. 12 was selected as being suitable for modification according to this process. Transmission curves showing filter No. 12 unperforated and with 20, 30, 45 and 60 percent, holes are found in Fig. 8 and indicate how the abrupt slope between 500 mμ and 550 mμ and the cut-off beyond 500 mμ may be modified to meet the requirements.

To aid in finding the best ratio of holes the curves were recomputed in terms of density instead of transmission. Since density is the negative logarithm of the transmission the effective

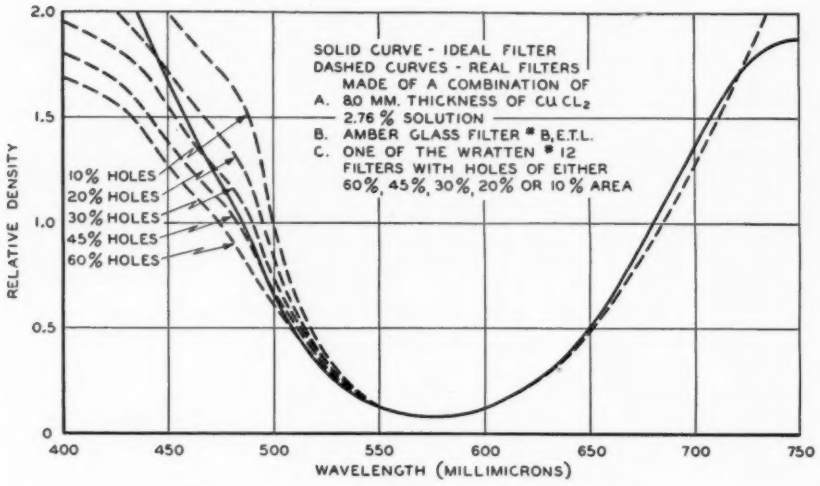

FIG. 9. Comparison of ideal with practical filters.

density of any combination of filters in series is the sum of the individual densities of the components and a density chart greatly facilitated the search for the required filter. These curves, which are shown in Fig. 9 indicated that the best result would be obtained with 45 percent holes in the Wratten filter.

The transmission of the triple filter combined with the sensitivity curve of the photoelectric cell gives a resultant response curve which is shown in Fig. 10. The concordance, while not perfect, at least looks promising.

To make a rigorous test of this combination the transmission of certain colored filters, the photometric transmission of which was accurately known, was measured by the photoelectric photometer, using an incandescent lamp at a color temperature of 2360°K as a source of light. The very satisfactory results appear in Table II.

From the above data it was concluded that as far as this feature is concerned the photoelectric photometer was capable of giving results in eclipse measurements with a high degree of accuracy.

Optical system

The photoelectric cell was attached to one end of an aluminum tube 2½ inches diameter and 22 inches long which contained an optical system designed for these objectives: (1) The collection of an adequate flux of light. (2) The delivery of this flux uniformly upon a fixed area of the photosensitive surface. (3) The exact delimitation of the area of sky under observation and the ability to vary this area by a measurable amount.

The optical system is shown diagrammatically in Fig. 11.

TABLE II.

Filter	Color	Photometric transmission	Trans. by photoelectric photometer	Error (percent)
Davis and Gibson 2360°K to M.N.Sun	Bluish	0.1352	0.1341	−0.8
Wratten No. 86	Amber	0.617	0.612	−0.8
Wratten No. 78A	Medium Blue	0.287	0.284	−1.0
Wratten No. 78B	Light Blue	0.482	0.487	+1.0

In this system, "the test plate lens" casts an image of the sky onto the plane of the iris diaphragm. The "intermediate lens" focusses an image of the test plate lens onto the diffusing ground glass plate placed in front of the photoelectric cell. The correcting filter is placed between the diffusing plate and the photoelectric cell. One of a series of neutral filters may be placed in front of the test plate lens to extend

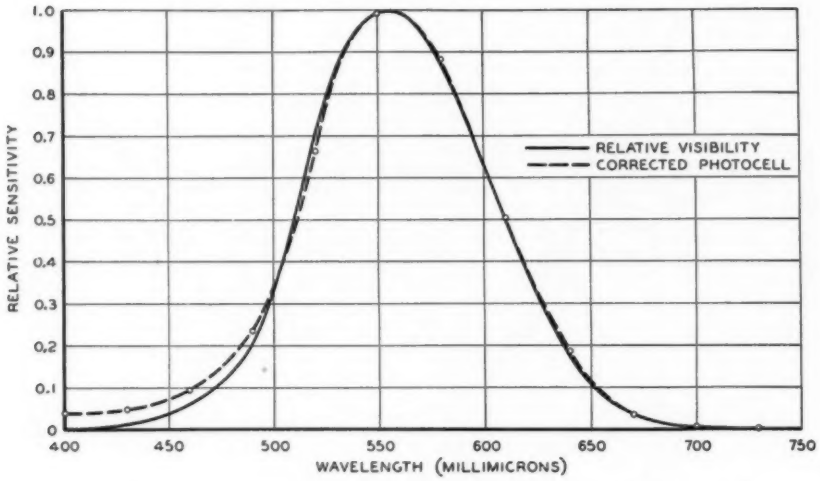

FIG. 10. Relative spectral sensitivity of human eye and corrected photo-cell.

the range. The iris diaphragm enabled the flux from an area of sky up to a diameter of 6 angular degrees to be admitted to the diffusing plate. An indicator affixed to the diaphragm showed the amount of the opening. A simple form of finder was attached to the exterior of the tube so that the tube could be directed upon the sun with an accuracy of better than two minutes of arc. The photometer was mounted on a rugged tripod with a well-constructed altazimuth head.

Amplifier

Calculation showed that the minimum flux of light which would be admitted to the photoelectric cell was of the order of 2.4×10^{-4} lumens. To make this minute flux measurable with field equipment a General Electric FP-54 Pliotron was used as an amplifier in a conventional circuit shown in Fig. 12. The resistance R_p was introduced into the plate circuit to make the mutual conductance of the tube more constant over the range in applied grid voltage. By adjusting the various potentials and resistances in the circuit for the particular characteristics of the Pliotron used, it was possible to secure a linear relationship over a sufficient range between photo-cell current and the increment in plate current.

Method of taking records

It was planned that records should be taken not only by eye but also by a moving picture camera. The principal thing to be recorded was the spot of light of the reflecting galvanometer and the intensity of this spot was great enough so that it could be photographed directly. The field of the camera took in also the index of the ring carrying the neutral filters and the indicator of the iris diaphragm and a clock. These were lighted locally with an illumination of about 100

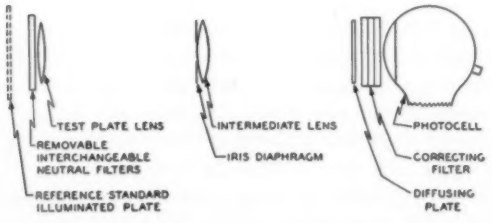

FIG. 11. Optical system of eclipse photometer.

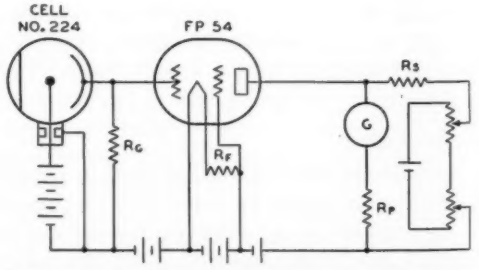

FIG. 12. Circuit diagram. Amplifier for eclipse photometer.

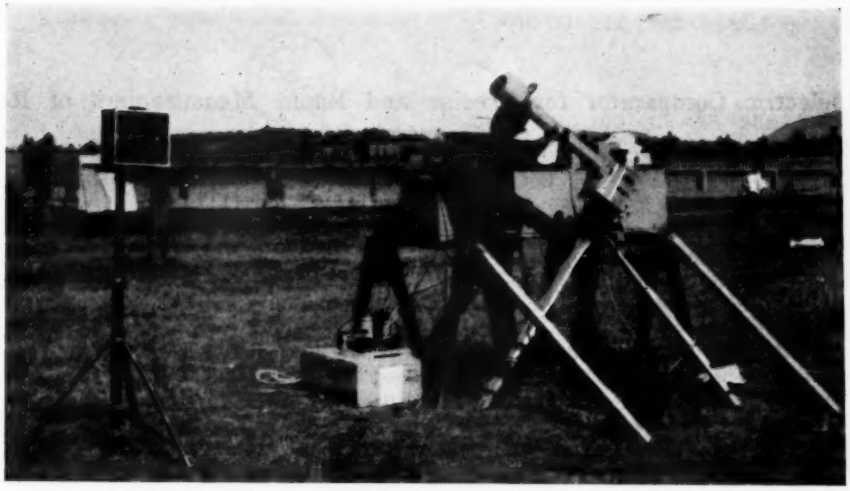

FIG. 13. Photoelectric photometer in the field.

footcandles and the indices were of large size, painted white, so that they would photograph readily. The entire set-up is shown in Fig. 13.

Method of calibration

The photometer was calibrated in the laboratory by setting up a standard lamp at a known distance. To check the calibration of the photometer in the field a portable photometric standard was made consisting of an automobile headlight lamp enclosed in a cylindrical housing containing a series of ground glass disks so that on the last disk a thoroughly diffused illumination was produced of known value when the lamp was held at a given voltage. This standard was readily affixed to the end of the photometer tube and afforded a means for precise checking in full daylight.

On the morning of August 31st the readings of this photometer were checked against simultaneous readings of the visual corona photometer and they were found to be in accord.

A Photoelectric Comparator for Precise and Rapid Measurement of Reflection and Transmission

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(Received April 20, 1933)

An apparatus is described, designed especially for the determination of reflection and transmission factors either in white light or in the various regions of the spectrum. A beam of light emerging from a lamp or from the slit of a monochromator falls at 45 degrees incidence upon a rotating glass disk, one-half of the surface of which is silvered. This splits the beam into two beams passing in alternation over two separate paths and through variable sectors by which their intensity may be decreased in a measurable manner. The sample is placed in one beam. The beams are reunited on the surface of a photoelectric cell, the current of which is amplified. In the output circuit is a vibration galvanometer tuned to the frequency of the two light beams, which is used as a null instrument. A strict substitution method is used in making the measurements. The spectral range which can be covered is determined by the character of the source of radiation by properties of the optical train and by the response characteristics of the particular photoelectric cell employed. Different cells can be used for different regions. In use, the apparatus has shown itself to be satisfactory from the point of view of high accuracy, rapidity and simplicity of operation.

IN applications of photoelectric cells to radiometry (including photometry) that method in which the cell is used as an indicator of equality between two beams of radiation, one of which is taken as a reference standard, the other being balanced against it, is open to the least theoretical objection. When so used the linearity or nonlinearity of both cell and amplifier has no influence upon the measurement. If, moreover, the comparison between the two intensities is made cyclic with a short period, the influence of changes in the sensitivity of the cell and of the amplifier is eliminated. This independence gives a preeminence to this method of using a photoelectric cell over all other methods.

Apparatus embodying this method of application in the photometry of lamps has been in constant use at Electrical Testing Laboratories for over six years with satisfactory results.[1] The light from a test lamp and a comparison lamp moving on a graduated track meet at right angles at the surface of a rotating glass disk placed at an angle of 45 degrees to each beam. This disk is silvered and left clear in equal sectors equally spaced. Behind the disk is placed the photoelectric cell in such a manner that the light from one lamp passing through the unsilvered sectors and the light from the other lamp reflected from the silvered sectors falls on it, each in its turn. The current from the photoelectric cell is amplified and if the beams from the two lamps do not produce equal illuminations on the cell this fact is indicated by an alternating current at the output of the amplifier. Thus, two beams from two sources of light are united by the action of a rotating disk.

In a comparator to be used in measuring transmission or reflection factors, it is desirable to split the light from a single source into two beams in one of which the sample to be measured may be interposed and one or both of which traverses a device for varying the intensity of the light in a measurable manner. The two beams are afterwards reunited at the photometric device and the establishment of a condition of equality of the two beams constitutes the operation to be performed in making measurements. Since both beams are supplied from the same lamp the effect of fluctuations in its intensity is eliminated.

In the comparator here described a photoelectric cell is used as a detector of equality and the rotating sector mirror is used to split the beam from a single source rather than to unite

[1] Sharp and Kinsley, Trans. Ill. Eng. Soc. **21**, 117 (1926); Sharp and Smith, *ibid.* **23**, 429 (1928).

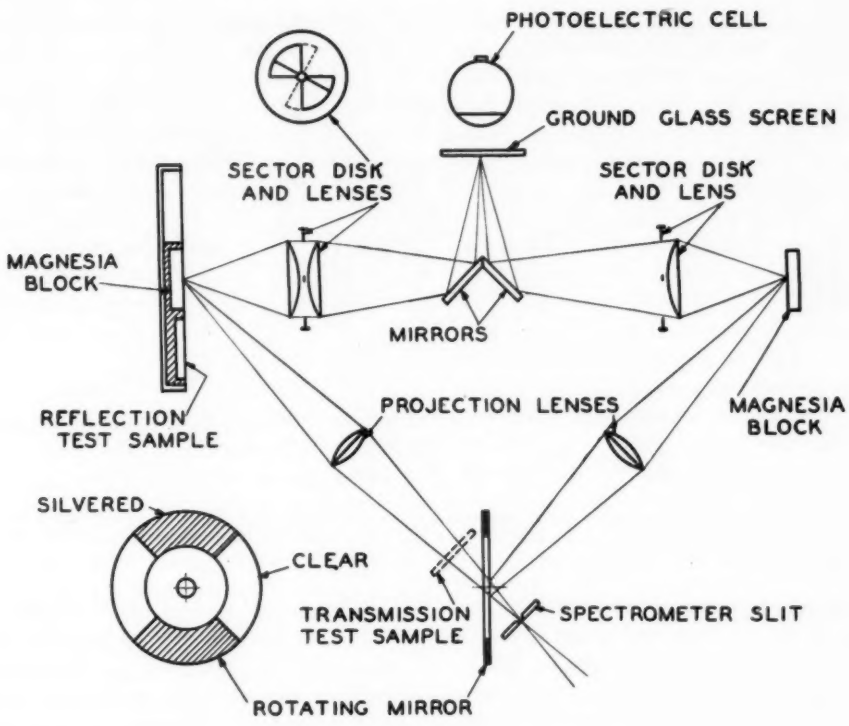

FIG. 1.

the beams from two different sources. The fluctuations of the current from the photoelectric cell which are present if the responses from the two beams are not equal are amplified and a vibration galvanometer is used as a detector of the presence of such fluctuations.

The most important application of the device is in spectrophotometry. In this application the source of light is the exit slit of a spectrometer or monochromator. Referring to Fig. 1 which shows schematically a plan of the comparator, the light proceeding from the slit strikes first the circular glass disk which is designated as a rotating mirror and which is driven by a synchronous motor, not shown in the diagram. The disk has equal segments silvered and unsilvered. The diagram shows two silvered segments and two clear segments. The number of segments depends upon the speed of the motor and upon the desired frequency of alternation of the beam. In the apparatus described the segments are as shown in the diagram and the disk is directly driven by a 4-pole, 25-cycle motor which gives to the beams of light a frequency of 25 cycles per second. The mirror splits the beam into two beams at right angles to each other. Each of these beams enters a projection lens which forms an image of the slit on a magnesia block.[2] The light from the magnesia blocks is collected by other lenses and after reflection from the two mirrors nearly at right angles to each other is thrown on to a ground-glass screen placed immediately in front of the photoelectric cell. The purpose of the ground glass is to diffuse the light with some uniformity over the sensitive surface of the cell.

In conjunction with each of the collecting lenses is an adjustable quadrant sector as shown

[2] The use of magnesia is not essential. It is desirable that the surface of the blocks should be white and of high reflecting power. In case more light is needed it is possible to use a glass mirror with a sandblasted surface for the right-hand block. To measure reflection factors a magnesia block or its equivalent is essential as a standard of white.

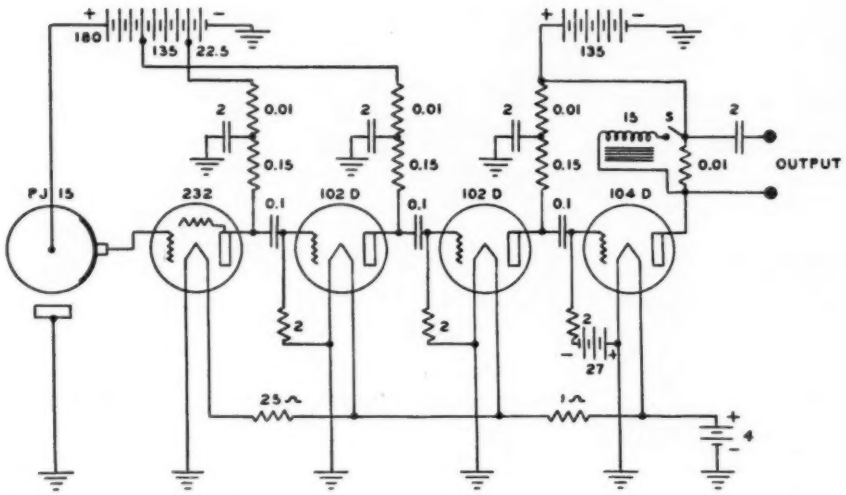

FIG. 2. Amplifier circuit for a.-c. spectrophotometer. Notes: 232 operated below rating to diminish grid current. Switch *S* allows for a choice of inductive reactance or resistance in the output circuit.

in the upper left-hand portion of the diagram, which serves to cut down the light in a measurable manner. A scale of 0 to 100 is attached to the left-hand sector, so that the amount of its opening may be read. It is not necessary that there should be a scale on the right-hand sector since this serves for comparison purposes only in the usual use of the instrument.

For ordinary spectrophotometric work a gas-filled caesium cell which is sensitive over the entire visible spectrum is used. For work extending into the infrared another gas-filled cell sensitive in this region replaces the first. Even with very high sensitivity due to the gas ionization the currents set up are in many cases extremely small and the use of a high-gain and stable amplifier is imperative.

The literature contains various proposals for high-gain low-frequency amplifiers and presumably various ways could be followed in constructing an amplifier suitable for this instrument. The circuit which we have employed is shown in Fig. 2, which is self-explanatory. Particular attention should be called to the necessity for adequate shielding not only of the entire amplifier and battery leads but also of each amplifier stage from the others and this has been carried to the extent of placing the plate resistors in separate compartments by themselves. It will be noticed that the cathode of the photoelectric cell is connected directly to the grid of the first tube without a grid resistor. This connection, as has been pointed out by others, leads to a uniform absolute sensitivity with all degrees of illumination of the cell. Its effective employment requires that the grid current shall be as small as possible and this condition is fulfilled by using a tube with the control grid lead coming from the top, thereby favoring high insulation, and by reducing the filament current and plate voltage.

In constructing the amplifier such tuning as is applicable should not be lost sight of. Since the frequency of the output is the same as that of the input of the synchronous motor it was necessary that the latter also should be shielded by enclosing it in a metal box. If a 60-cycle motor were to be employed together with a two-part instead of a four-part rotating mirror a condition would be attained in which the frequencies differ and this sort of disturbance would very likely not be felt. However, the speed of a 60-cycle, four-pole motor is perhaps a little high for a glass disk. Obviously, this difficulty could be overcome by the use of simple gearing and then the lamp which supplies the light to the monochromator as well as the synchronous motor could be operated from the same 60-cycle supply.

A synchronous motor is used in order that the frequency of the beam alternations may be a fixed frequency to which the vibration galvanometer is tuned. The equality of the two beams on the cell is determined by the spot of light from the vibration galvanometer narrowing down to its minimum width. The vibration galvanometer has very great advantages for use in this connection because of its high sensitivity, its freedom from static friction and its relative insensitivity to other frequencies than the one to which it is tuned.

Method of Operation

As illustrating the method of operation let it be supposed that the transmission factor of a transparent sample is to be determined. The sample is interposed in the left-hand beam as shown in the diagram. The measuring sector in the left-hand beam is set at 100 on the scale. Then the aperture of the sector in the right-hand beam is adjusted until the vibration galvanometer indicates a balance of the two beams. The sample is then removed from the beam and the measuring sector is closed down until equality has again been established. The reading of the scale then gives the percentage transmission of the sample.

If a reflection sample is to be measured it is placed in a holder so that either it or the magnesia block may be set at the point where the left-hand image of the slit is formed. With the sample in this position, the beams are balanced by using the right-hand sector. Then, the magnesia block is substituted and the balance restored by closing the left-hand measuring sector. The reading of the sector then gives the reflection factor of the sample in terms of the reflection factor of the magnesia under conditions of 45-degree incidence and normal viewing which is generally adopted in work of this kind. If the absolute value of the reflection factor is required a correction for the one or two percent absorption of the magnesia block must be introduced. A reproducible standard of white for this purpose is conveniently made by smoking a piece of magnesium carbonate with magnesium oxide from a burning magnesium ribbon.

The method of use described is a strict substitution method—a procedure always preferred in precise photometric measurements. In spectrophotometry it requires two settings for each color, namely, the setting with the sample and the setting with the magnesia block. It would appear that this should not be necessary and that it should be possible to adjust the sectors for a balance of white against white and to have the balance obtain for any color of the spectrum. This would require a similarity in the paths of the two beams and the same number of silver reflections in each of the two beams. It is the result of our experience, however, that because of the spottiness of the sensitive surface of photoelectric cells, which results in different response characteristics in different regions, such a constant reading of white against white throughout the spectrum is unattainable with any high precision. We have not found it possible to draw a reproducible curve showing the ratio of white to white for all wave-lengths which may be used as a characteristic curve of the instrument. For approximate readings this may do well enough but for real precision, that is where reflection or transmission factors are to be obtained accurately to within one figure on a scale of one hundred, the substitution method affords the only reliable means.

The substitution can be carried out in other ways especially if the left-hand sector disk carries a scale by means of which its aperture can be read.

Evidently the comparator may be used for other purposes as, for example, the transmission and reflection values of neutral substances for white light. The determination of the contrast ratio of printing papers where the reflection from a paper is measured first with a white background and next with a black background is a simple matter. With suitable auxiliary devices the comparator might also be used for microphotometry in the measurement of the relative intensity of spectral lines on a photographic plate. For this purpose a sharp image of a narrow slit would need to be focussed on the plate, which would then be treated as a transmission sample.

In practice the instrument has been found to be simple, precise and rapid. The spectral range which it is able to cover depends among other things upon the photoelectric cell used. With a

suitable cell and monochromator accurate infrared measurements are made with no difficulty. Cells can be changed in a few moments and with the instrument described measurements have been made from 400 millimicrons to 1200 millimicrons. The comparator can be used by an operator without scientific training and results obtained which, under conditions where there is a reasonable sensitivity, repeat themselves within a few tenths of a percent, so that in ordinary work a single setting for each wave-length is all that is required. In view of this fact and of the further fact that the answer may be set down as obtained without the necessity of making any corrections whatever, the total time required to make a test is probably as short as with any other instrument which is at all comparable in precision.

In conclusion it should be noted that the above apparatus is designed to operate in accordance with the principles for the best use of photoelectric cells in photometry as laid down by Ives[3] and Kingsbury. The curve-drawing colorimeter of Hardy[4] could by suitable modifications and by the elimination of the curve-drawing feature be operated in accordance with the methods here described. It should be noticed that Hardy uses the rotating mirror for combining two beams in practically the same way as is described by Sharp and Kinsley.[1]

The apparatus here described, which really is an auxiliary apparatus to be used in connection with any suitable monochromator if spectrophotometric measurements are to be made, has important advantages with respect to simplicity, accuracy and lower cost which render it a very practical instrument in many applications.

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[3] Ives and Kingsbury, J. O. S. A. **21**, 541 (1931).

[4] Hardy, J. O. S. A. **18**, 96 (1929). This instrument has been developed commercially in altered form by the General Electric Company.

Efficiency of the Chemiluminescence Accompanying Oxidation of Grignard Compounds

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(Received April 24, 1933)

THREE types of luminescence are known to be associated with solutions in ether of the compounds known as Grignard reagents: (a) fluorescence, shown weakly by the compounds themselves, and very strongly by the oxidation products of the compounds; (b) chemiluminescence, shown when the compounds are oxidized by oxygen, air, or certain other oxidizing agents, and also, in what appears to be a different process, when the compounds react with chloropicrin or bromopicrin; and (c) galvanoluminescence, which appears at one or both electrodes when the solutions undergo electrolysis. The compounds involved have the general formula RMgX, in which R is an organic radical, and X is a halogen atom. They are prepared, usually in anhydrous ethyl ether, by direct reaction of the magnesium with the halogenated hydrocarbon (RX) compounds. They react rapidly with oxygen, and even more rapidly with water; but the latter reaction is not accompanied by luminescence.

Each of the types of luminescence mentioned has been given a considerable amount of study. So far as the fluorescence is concerned, it must be admitted that but little is known about it; but it has been found that the spectra of the fluorescence of the oxidation products of such compounds as p-ClC_6H_4MgBr frequently contain three bands, while the chemiluminescence spectra are single-banded. Typical spectra have been published in an earlier article[1] in this journal. These spectra seem to indicate that the fluorescence and the chemiluminescence are produced by different mechanisms, presumably in different substances.

The chemiluminescence phenomena have been given much more extended study. The reaction with chloropicrin was discovered first[2]; the luminescence with oxygen seems to have been discovered independently by a number of workers. The earlier references barely mention the existence of the effect;[3, 4, 5] several short investigations[6, 7, 8, 9, 10, 11] followed. More extensive study showed[12, 13] the existence of definite and interesting relationships between the chemical structure of the reacting compounds and the physical characteristics of the luminescent radiation. Most of the results have been confirmed by other workers.[14] It is now well established that a cyclic structure of the organic radical is favorable to the production of light during oxidation; and that unsaturation is also favorable. Thus, benzene-ring compounds give much more light than cyclohexane derivatives, and the latter give more light than aliphatic (chain) compounds; these last give only a very faint light, and that only at rather low concentrations.[15] It is found best to have the magnesium attached directly to an unsaturated carbon atom, as in the benzene derivatives. It is also found that if certain other atoms or radicals are substituted for one of the hydrogen atoms of the benzene ring, the bright-

[1] Dufford, Nightingale and Calvert, J. O. S. A. and R. S. I. **9**, 405 (1924).

[2] E. Wedekind, Ber. **4**, 417 (1906). Phys. Zeits. **7**, 805 (1906). Chem. Zentr. **30**, 921 (1926). Zeits. f. wiss. Phot. **5**, 29 (1927).

[3] A. Heczko, Chem. Zentr. **35**, 199 (1911).

[4] E. Schmidlin, Ber. **45**, 3172 (1912).

[5] L. Spaeth, Monatsh. f. Chem. **36**, 4 (1915).

[6] S. Moeller, Arch. Phys. Chem. **21**, 449 and 466 (1914).

[7] J. Lifschitz, Helv. Chim. Acta **1**, 482 (1918).

[8] Lifschitz and Kalberer, Zeits. f. physik. Chemie **102**, 393 (1922).

[9] Evans and Dufford, J. Am. Chem. Soc. **45**, 278 (1923).

[10] Gilman, McGlumphy and Fothergill, Rec. des Trav. Chim. des Pays-Bas **49**, 526 (1930).

[11] Gilman, Fothergill and McGlumphy, Rec. des Trav. Chim. des Pays-Bas **49**, 726 (1930).

[12] Dufford, Calvert and Nightingale, J. Am. Chem. Soc. **45**, 2058 (1923).

[13] Dufford, Nightingale and Calvert, J. Am. Chem. Soc. **47**, 95 (1925).

[14] Evans and Diepenhorst, J. Am. Chem. Soc. **48**, 715 (1926).

[15] R. T. Dufford, J. Am. Chem. Soc. **50**, 1922 (1928).

ness is increased; the increase is much greater if the substituent is in the position para to the magnesium than if in the ortho or the meta positions. However, more than one substituted group appears to hinder rather than help the luminescence. Double and triple ring compounds, such as naphthalene and anthracene derivatives, are luminescent; especially the naphthalene compounds which have the $-MgBr$ group in the beta-position. The nature of the substituted groups, as well as the nature of the reacting halogen, affects profoundly both the intensity and the color of the luminescence.

The present paper describes a continuation of the studies just described; it is devoted to a quantitative study of the chemiluminescence accompanying the reaction of the Grignard solutions with oxygen. A similar study of the reaction with chloropicrin is in preparation. It continues a program which started with the quantitative study of the galvanoluminescence of the Grignard compounds and other substances.[16, 17, 18] The galvanoluminescence appears not to come from the same mechanism as the chemiluminescence, in spite of the similarity of spectra, since (a) its brightness is by no means proportional to that of the chemiluminescence of the same compounds; (b) it is obtainable under conditions which appear to exclude the possibility of reaction with oxygen; and (c) it is obtainable from $MgBr_2 \cdot 2(C_2H_5)_2O$, for example, which is a substance which gives no chemiluminescence and does not react with oxygen. In the case of the galvanoluminescence, it was a relatively easy matter to measure the electrical energy input, to determine photometrically the amount of luminous flux given out, and then, on the basis of 620 lumens per watt, to compute an efficiency for the process. In the galvanoluminescence, brightnesses up to 2×10^{-5} lamberts have been observed in Grignard solutions, and values several times that large have been found in aqueous solutions, the best results occurring there with aluminum electrodes. The highest efficiency found was from the ether solution of $MgBr_2 \cdot 2(C_2H_5)_2O$, which gave a value of 4.5×10^{-4} percent, or 2.8×10^{-4} lumens per watt, when a platinum electrode was used. Curiously, the highest efficiency occurs at much lower voltages with this substance than with any of the Grignard solutions.

In the present work, which attempted to determine the efficiency of the chemiluminescence obtained from Grignard solutions when reacting with oxygen, the same two main problems are encountered: (a) the determination of the total amount of energy released in oxidizing a known amount of substance, and (b) the determination of the energy equivalent of the total amount of light emitted in oxidizing a known amount of substance. Each of these problems offers peculiar experimental difficulties.

The first problem, that of determining the heat of oxidation of the substances studied, was attacked calorimetrically. The peculiar difficulties arise from the circumstances that the solutions must be protected from loss of ether by evaporation, the cooling effect of which would have introduced gross errors, and that the solutions must be protected from accidental contact with air, which would have caused premature oxidation of the material. Hence it was necessary to prepare and to handle the solutions under dry nitrogen, in nitrogen-filled vessels, pipettes, etc. When samples were taken from the flasks in which they were prepared, duplicate samples were taken at the same time for chemical analysis. The concentrations of the Grignard solutions were found by titration, by using a method due to Gilman.[19] This seems to be about the only method available for estimating aromatic Grignard compounds.

In order to avoid ether losses, calorimetric vessels of unusual design were used. These were made from small Pyrex flasks. Oxygen from a large tank, at a pressure about 6 to 10 lbs./in.^{2} above atmospheric, was introduced through a side tube sealed to the bulb of the flasks; this tube was coiled around the flask several times, so that the coils were immersed in the water of the calorimeter. The coils thus formed a reflux condenser, and any heat lost by evaporation of ether at the place where the reaction was progressing was thus returned to the calorimeter

[16] Dufford, Nightingale and Gaddum, J. Am. Chem. Soc. **49**, 1858 (1927).

[17] Dufford, J. O. S. A. and R. S. I. **18**, 17 (1929).

[18] Sullivan and Dufford, J. O. S. A. **21**, 513 (1931).

[19] Gilman, Wilkinson, Fishel and Meyer, J. Am. Chem. Soc. **45**, 150 (1923).

by condensing the ether again in the coils. The incoming stream of oxygen tended to prevent ether from escaping beyond the coil, and the ether tended to regulate the rate at which oxygen entered, so that the reaction proceeded at a uniform rate. It was necessary to open a valve at the neck of the flask at the beginning of each run, for a fraction of a second, to allow the nitrogen to escape; blank tests showed that doing this did not give rise to any measurable temperature changes. Stirring was obtained by shaking the flask. Temperature changes were read with a Beckmann thermometer. With this apparatus, surprisingly consistent results were obtained.

The values so obtained for the heats of oxidation of sixteen Grignard compounds are assembled in Table I. The values are means of the number of determinations stated; the different determinations usually differed from the mean by less than 1 percent. The corrections for radiation, thermal capacity of reacting material, etc., were applied; but no correction for heats of solution was made, for lack of data. The results show that, as a class, chlorine-bearing compounds have higher heats of oxidation than the corresponding bromine compounds, and that the latter have higher heats of oxidation than the corresponding iodine compounds (C_2H_5MgI is an exception). They show that in the propyl derivatives, the iso compounds have higher heats of oxidation than the normal compounds. Further, they confirm in striking fashion the conclusion of Lifschitz and Kalberer[8] that there is no correlation between heats of oxidation and brightness of luminescence of the compounds. These authors give the following results for the heats of oxidation of the compounds they studied: C_2H_5MgBr (7 tests) 58.2 kcal./mole; C_2H_5MgI (4 tests) 59.7 kcal./mole; C_6H_5MgBr (8 tests) 65.1 kcal./mole. These values are all considerably lower than those given above in Table I. The reason for such a difference is uncertain. It may be that Lifschitz and Kalberer applied a correction for heats of solution that could not be applied in the present work. They state that they estimated the ether losses, and applied a correction for them; in the present work, the necessity for such a correction was avoided. They do not state how they measured the concentrations of their solutions. In the present work, any errors likely to occur in measuring the concentrations would tend to overestimate the amount of material present, thus making the results too low rather than too high.

TABLE I. *Heats of oxidation of Grignard compounds.*

Substance	No. of tests	Kilocalories per mole
(*a*) *Aliphatic Compounds*		
C_2H_5MgCl	3	86.0
$C_6H_5CH_2MgCl$	4	74.2
n-C_3H_7MgCl	4	82.8
i-C_3H_7MgCl	4	91.4
CH_3MgBr	3	71.1
C_2H_5MgBr	7	72.8
$C_6H_5CH_2MgBr$	4	62.5
n-C_3H_7MgBr	4	81.8
i-C_3H_7MgBr	4	86.3
CH_3MgI	4	67.8
C_2H_5MgI	4	76.1
(*b*) *Aromatic Compounds*		
C_6H_5MgBr	4	71.7
C_6H_5MgI	8	47.1
p-ClC_6H_4MgBr	3	70.7
p-BrC_6H_4MgBr	9	67.6
p-$CH_3C_6H_4MgBr$	4	72.3

In three cases, heats of oxidation were determined for a given substance at quite different concentrations. The agreement between the determinations was close. The values obtained at the higher concentrations were slightly higher, but not enough so that the difference was certainly outside the probable accidental errors. Hence any correction for heats of dilution would apparently be small. The solutions of *p*-BrC_6H_4MgBr sometimes form double layers. This behavior may be due to the presence of $MgBr_2 \cdot 2(C_2H_5)_2O$, which always forms such layers if the concentrations permit. The titrations showed that the lower layers contained a higher concentration of the Grignard compound; but the average of the heats of oxidation found from the different layers was practically identical with the average found from solutions which never separated into layers. Another interesting result was obtained. The compound formed in the reaction of $C_2H_4Br_2$ with magnesium, which at first was thought to be BrC_2H_4MgBr because of its strong similarity in behavior to the Grignard solutions, appears to be $MgBr_2 \cdot 2(C_2H_5)_2O$, the yield apparently being quantitative. It was found that the presence of this substance caused no errors either in measuring the heats of oxidation

or in the titrations upon which the concentration measurements depended.

The second problem, involving the photometric measurements, was attacked by optical rather than photoelectric methods, for several reasons. The difficulties arose from the facts that not only were the sources of light of unusual nature, but were very faint compared with those met in ordinary photometric work.

The solutions were oxidized in small Pyrex flasks, under conditions essentially similar to those under which the heats of oxidation were determined. In this case, the flasks were held at the center of a small specially-built Ulbricht sphere; and instead of shaking the flask, stirring was accomplished by means of a small mercury-sealed motor-driven stirrer. A translucent screen between the flask and the window of the sphere was made of such thickness that it appeared to have the same brightness as the walls beyond it. A brightness photometer which had been used by Sullivan and Dufford[18] was available; and after its calibration had been rechecked against brightness standards calibrated by the Bureau of Standards, it was used to measure the window brightness of the sphere. It was assumed that the window brightness was proportional to the candlepower of the source in the sphere. A 25-watt lamp was calibrated for mean spherical candlepower, against the available photometric standards. Such a lamp, of almost exactly the same size as the reaction flasks, could be substituted for them in the sphere, and the brightness reading for a known candlepower thus found. Essentially, the method used was a substitution method. Later, the calibration of the combined sphere and brightness photometer was checked against the curve for another standard lamp calibrated for mean spherical candlepower at the Bureau of Standards. The results checked to about 2 percent; this was considered satisfactory, since the standards themselves were good to only ± 5 percent. Because of this uncertainty, as well as the other experimental difficulties, the writers do not wish to claim that the final results do much more than to establish the order of magnitude of the effects studied; but even such results are of considerable importance in the present case, and are about as good as could be expected.

In making the photometric observations, a measured volume of solution (of a concentration determined by titrating a sample taken simultaneously) was placed in a reaction flask, and kept under nitrogen until ready for observations. When the flask was in place in the sphere, and the stirrer in action, the nitrogen was expelled and oxygen admitted from the same tank as was used in the calorimetric experiments. Readings were taken at half-minute intervals from the instant that the oxygen was turned on until the light became too faint for further measurement. The readings were all made at night. Two observers were used; one, with eyes specially dark-adapted, adjusted the photometer to balance, while the other, using a faint red light behind a screen out of sight of the first observer, read the meters, gave the time signals, and recorded the readings. The results gave a curve showing the mean spherical candlepower of the source, as a function of the time. The shape of the curve is of no theoretical significance, as it depends on the rate at which oxygen is admitted. A sample curve is shown in Fig. 1. These curves were integrated

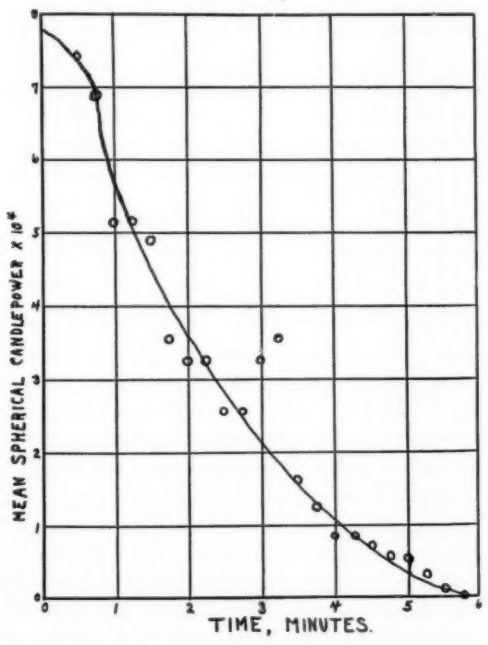

FIG. 1. A typical curve, mean spherical candlepower as a function of time, obtained from the oxidation of *p*-ClC_6H_4MgBr. The area under this curve is 0.00169 m.s.c.p.-minutes.

with a planimeter; several determinations were made for each. The results give the product of total luminous flux emitted and time; and, allowing 620 lumens per watt, as if the light had been given out at the wave-length of maximum visibility, the luminous energy given out per mole in the oxidation process could be computed. From this and the heat of oxidation, the total efficiency of the radiation process could be computed. The radiation efficiency would be higher, since of course this method underestimates the amount of energy radiated; but since the radiation efficiency tells nothing about the visibility of the radiation, and hence nothing of its possible usefulness for purposes of illumination, it was decided to measure total luminous efficiency, as was done in the preceding investigations.[17, 18]

The results for four of the brightest Grignard compounds are given in Table II. None of the other compounds gave enough light to permit measurements of the kind needed. The compound C_6H_5MgI gave light that was barely visible, but too faint to measure before it died out. Its efficiency would therefore probably not exceed 10^{-8} percent.

The absorption of light by the solutions reduces the observed candlepower to a figure somewhat below its true value. The effect of this is seen in the results for p-BrC_6H_4MgBr, in which the clearer upper layer gives the higher efficiency, but the average for the two layers comes out the same as for the solution in which no layers formed. Separate results are given for p-ClC_6H_4MgBr, to show the degree of consistency obtainable in the final results. It is interesting that this compound, which is the brightest of all those tested, shows the highest efficiency. The efficiencies found, while higher than many of those observed in the studies of galvanoluminescence, are by no means so high as was expected; and they do not reach the highest value found by Sullivan for the galvanoluminescence of $MgBr_2 \cdot 2(C_2H_5)_2O$. It is hoped that further comment on the significance of these results may be made in a following article in which the results of a similar study of the Wedekind reaction are to be communicated.

TABLE II. *Total luminous efficiencies of chemiluminescence.*

Substance:	Concentration (moles/liter)	Light-energy (joules/mole)	Heat of oxidation (kilocal./mole)	Total efficiency (percent)
C_6H_5MgBr	2.27	0.000392	71.7	1.31×10^{-7}
p-$CH_3C_6H_4MgBr$	1.01	0.00182	72.3	6.00×10^{-7}
p-BrC_6H_4MgBr (lower layer)	1.396	0.0169	65.6	6.14×10^{-6}
p-BrC_6H_4MgBr (upper layer)	0.810	0.0339	68.8	1.18×10^{-5}
p-BrC_6H_4MgBr (no layers)	1.190	0.0244	67.7	8.61×10^{-6}
p-ClC_6H_4MgBr (first test)	1.189	0.0690	70.7	2.33×10^{-5}
(second test)	0.992	0.0770	70.7	2.60×10^{-5}

The Description of a Case of Total Color Blindness

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(Received May 9, 1933)

TOTAL absence of sensitivity to color occurs so infrequently in the population as to place upon the discoverer of a case exhibiting this anomaly the responsibility of making a thorough description of it. Since the case described by Huddart in 1777, apparently the first recorded, there have been noted approximately one hundred and twenty-five occurrences of total color blindness. Of these less than a dozen have been found in this country. A careful search of the literature shows the case here reported to be but the eleventh. The present occurrence in a male, 23 years of age, hereafter to be designated J.M., yields little on analysis that is strictly new. Most of the observations were directed towards the amplification of information concerning a few controversial matters to be found in the literature of color blindness. If this report has in it anything of novelty it is that it includes a careful determination of the visibility function. While achromatopic luminosity has been measured in several cases,[1] this appears to be the first instance in which the visibility coefficients have been determined.

Most cases of total color blindness have been discovered through medical channels. Because of the refractive defects usually associated with total color blindness the ordinary complaint is that of poor general vision; the color defect has come to light as a secondary matter. In the present instance the subject knew of his color deficiency, which was a congenital condition, and when sought out by the writer gladly cooperated in the investigation. Conditions for experimentation have been nearly ideal since J.M., a graduate student, has been able to make highly intelligent observations and has given generously of his time.

As a preliminary routine procedure his performance on several standard color blindness tests was noted. Beyond the first design of the Ishihara, the "12," he could not proceed; all the remaining patterns failed to reveal figures or pathways. The Nagel cards again indicated the absence of any perception of color. Under pressure, card No. A-10 (one having a collection of red, green and grey spots) was selected as that having only "red or reddish" dots. After shuffling the pack the same card was picked as containing only "green or greenish" dots. The Holmgren Wool Test was equally meaningless; under instructions to sort out the skeins into four piles, red, yellow, green and blue, he concluded with five piles based solely on brightness differences. The spread-out spectrum, observed through a simple hand spectroscope, appeared as a series of graded brightnesses, each part shading into contiguous portions; no other differentiating features could be detected. Observation by J.M. of a uniformly illuminated surface through various of the Wratten filters immediately showed the red end of the spectrum to be markedly foreshortened for him. For example, the surface as viewed through filter No. 76, the violet of the monochromatic series, is very much brighter than when seen through No. 70 (red). Little difference is detected by the normal eye. Again, the field for a neutral tint filter having a transmission of approximately 0.001 is perceptibly brighter than for either No. 70 (red) or No. 71A (red-orange); this is the reverse of the normal judgment. These preliminaries thus not only proved the subject to be without color acuity but suggested that the visibility function was different from that present in normal color vision.

As in most cases of total color blindness there is a marked amblyopia, acuity being about one-tenth normal. Furthermore the dimness of vision is not conditioned by other optical defects.

[1] Some of the most reliable of such measurements are to be found in the report by Nagel and May, Zeits. f. Sinnesphysiol. **42**, 69 (1908) and that by Abney, Proc. Roy. Soc. (London) **A66**, 179 (1900).

J.M. is markedly myopic and astigmatic. The optimal correction for the right eye involves a −2.50 spherical lens and a −0.50 cylinder, axis 10°. The left eye requires a −2.00 spherical lens and a −1.00 cylinder, axis 90°. In the latter case the axis may be shifted to 180° without notably affecting acuity. All other refraction changes may be very gross without further serious impairment of vision. The essential defect is thus a retinal one and refractive errors are of minor importance.

Another characteristic of this case, one which seems to be not uncommon in total color blindness,[2] is the presence of a slight divergent strabismus. The eye suffering the least alteration of acuity, the left, is somewhat preferred in the determination of fixation. While the lack of binocular coordination is not marked there is a varying tendency for their lines of regard to be drawn slightly apart. Correlation with findings concerning dioptric disturbances is seen in the fact that the left eye is dominant.

More notable than the defects just mentioned is the partial closure of the lids habitually displayed by the subject. In common with other cases he exhibits the symptoms ordinarily summed up in the term "photophobia." The eyelid response is a protective one and serves to supplement pupil contraction in cutting down the dazzling effect of even moderate intensities of light. Bright illuminations are regularly avoided since exposure to them immediately produces a glare which, while not painful, plunges him into a temporary "daze," a condition which is, to say the least, inconvenient. The matter of crossing the street on a bright day may be an exciting adventure unless discrimination is exercised in the choice of visual objects. To be sure, dark glasses are indicated as a measure making for economy of energy and these are resorted to occasionally. J.M. wore them regularly as a boy but has since quit them because of their conspicuous nature.

Another somewhat obvious condition found here is nystagmus. There are quite constant lateral movements of the eyes, the excursions becoming particularly short and jerky when fixation of a small object is demanded. The extent and regularity of the nystagmic movements are dependent to some degree upon the amount of illumination and previous condition of adaptation though there are notable fluctuations in this regard from time to time. There have been days on which the subject seemed to have eye movements entirely normal in appearance. Variability in this matter has been encountered before; Grunert,[3] e.g., observed a totally color blind case in which there was an appreciable lessening of the nystagmus over an eleven year period.

At one time the question of whether there invariably exists a central scotoma in total color blindness was an exciting one since the answer was regarded as critical for the Parinaud-von Kries duplicity theory.[4] The failure of Hering and Hess to find a foveal blind spot led them to doubt the validity of the theory. König's success in demonstrating the existence of one in his case was regarded as strong evidence in favor of duplicity. It is fortunate for the theory, which has since become fact, that the matter is not as critical as was at first supposed, since there has been a failure to demonstrate central scotoma in fully half of the cases tested for it. The difficulties attending exploration of the retina of a nystagmic eye are obvious. The infrequency with which central scotoma has been found is undoubtedly attributable in large part to the impossibility of getting steady fixation. Unless there is a "substitute fovea," such as was apparently present in the case investigated by Ladd-Franklin,[5] it is difficult to discover the normal blind spot, much less a foveal scotoma. Nagel[6] has suggested, as has von Kries, that there may be a substitution for cone structure at the fovea of a rod population, thus accounting for the lack of a blind spot. The discovery that in some cases central vision is markedly improved by dim light may be urged in support of this hypothesis.

Clear-cut evidence for the existence of a central scotoma is lacking in the case of J.M. despite several attempts to locate it. The most careful test was made with a multiple point field

[2] Parsons, *Colour Vision*, p. 198 (1924).

[3] Grunert, Arch. f. Ophth. **56**, 132 (1903).

[4] A statement of the relation to the duplicity theory is to be found in Nagel's appendix to Helmholtz's *Physiological Optics* (O.S.A. translation), **II**, 379–380.

[5] Ladd-Franklin, *Colour and Colour Theories*, p. 99 (1929).

[6] Reference 4, 380–381.

in the dark room, according to the specifications of Ladd-Franklin.[7] Two somewhat complex patterns of tiny luminous points were tried, the subject being instructed to fixate one point after another, the hope being that at some position of the eye certain of the lights would be missing from the pattern. Such was not the result, however. The only suggestion of foveal insensitivity came from a procedure in which the image of a small white test object, reflecting daylight, was allowed to fall on different retinal areas. A consistent dimming was noted whenever the object was brought into the line of regard. The proof of central scotoma is far from complete and what evidence was forthcoming is perhaps best interpreted in terms of Nagel's suggestion.

Pupil reactions in total color blindness have been observed by Hess and by Engelking,[8] the former having found responses to alternate dark and light fields to be missing, the latter having noted reactions equal in extent to but more sluggish than normal responses. Observations made with a pupillometer on J.M. showed an almost total lack of response. With light having an intensity of 0.074 f.c. at the eye only a very minute and immeasurable twitch of the pupil was observed. For the same conditions the normal response is a reduction of pupil diameter of the order of 1.6–1.8 mm. The maximum response obtained under any of a wide range of light intensities used was but 0.2 mm. There is thus little doubt that pupil responses play no important rôle in the behavior of this case.

All of the observations recorded thus far concur in pointing towards the simple explanation that the entire visual function is here mediated exclusively by the rods. All behavior is in line with the supposition that the cone system, normally responsible for color reception, is either missing or failing in function. There are, however, at least two possibilities clearly indicated in color theory. Besides the above-mentioned hypothesis there is the possibility, based upon the trichromatic theory of Thomas Young, that total color blindness may be due to an identification of the light absorbing substances in the three types of cones. To be sure, no clear-cut case has yet appeared which is explicable on the latter grounds. Raehlmann's famous color blind[9] is the nearest approximation to it but there the luminosity distribution worked against the theory. Fortunately it is possible to decide between the possibilities that present themselves. It is only necessary to make a measurement of the visibility function to determine whether rods are exclusively responsible for vision or whether light reception involves cones. In the former case we should expect to come out with a characteristic scotopic visibility curve; in the latter the curve should be photopic. If the rods are responsible the point of maximum visibility should be in the green at 511 mμ, according to the most careful determinations;[10] if the cones are mediating vision the point of inflection should be in the yellow-green at 556 mμ.

Determination of the luminosity of the spectrum was made by directing the light from the exit slit of a Hilger spectrometer into the central field of the Lummer-Brodhun cube of a Macbeth illuminometer. The source of energy was a concentrated filament tungsten lamp. A neutral tint balanced wedge was interposed between the spectrometer entrance slit and the lamp. The outer field of the Macbeth was illuminated by the standard lamp of the instrument and was set at 3 f.c. Regulation of the wedge position was made by the subject, in each trial raising the brightness to the point where a match with the outer field was effected. A spectral band of 8 mμ was exposed for every 5 mμ separation in the critical spectral range and the energy necessary to produce a match with the outer field of the illuminometer was calculated from the wedge settings. The relative brightnesses of the various spectral positions are shown in Table I. For comparative purposes two other sets of luminosity data of total color blinds are given, that of the case measured by Nagel and May and the average values for three cases tested by Abney over a period of years. Both sets were obtained with the use of the Nernst lamp as a source of energy and, particularly at the extremes, are not entirely comparable with luminosity values derived from a tungsten lamp spectrum. While the

[7] Reference 5, 98–99.

[8] A review of this literature is to be found in B. Chance, Am. J. Ophth. **14**, 417–425 (1931).

[9] Raehlmann, Zeits. f. Augenh. **2**, 315 (1899).

[10] Hecht and Williams, J. Gen. Physiol. **5**, 1 (1922).

TABLE I. *Relative luminosity measurements for the critical range of the spectrum.*

Values for the present case, J.M., are derived from direct measurement. Those for the case reported by Nagel and May and for the three cases studied by Abney are interpolated from the curves presented by them.

Wave-length (mμ)	J.M.	Nagel and May	Abney
470	0.11	0.21	0.21
475	—	.25	.26
480	.17	.30	.33
485	.23	.35	.41
490	.28	.40	.49
495	—	.45	.59
500	.49	.49	.69
505	—	.58	.76
510	.64	.66	.83
515	.72	.74	.88
520	.80	.80	.93
525	—	.85	.96
530	.91	.92	.99
535	.95	1.00	1.00
540	1.00	0.98	0.98
545	0.91	.96	.95
550	.86	.94	.90
555	—	.88	.82
560	.62	.79	.76
565	—	.69	.64
570	.44	.59	.56
575	.35	.47	.45
580	.24	.34	.37
585	—	.32	.29
590	.12	.30	.24

energy distribution of the Nernst lamp and that of tungsten are very similar, the former has slightly higher emission in the red and in the violet. Considering these minor differences it is apparent that agreement between the three sets of data is very close and serves to establish identity of function in all the cases represented.

It is but one step from the measurement of luminosity values to the determination of visibility coefficients. To make the translation it is necessary to know the energy distribution of the source used in connection with the spectrometer as well as the dispersion of the instrument itself. A single correction may be made for both providing the radiant energy is measured after passing through the spectrometer. This was accomplished by inserting at the exit slit a photoelectric cell (Weston Photronic Cell, Model 594) connected to a sensitive galvanometer (L & N Type "R"). Since the cell response for an equi-energy spectrum has been ascertained[11] this provides a somewhat novel and by no means impracticable method of determining energy distributions; it has the advantage of avoiding many sources of error involved in the use of the thermopile or bolometer for similar measurements.

The visibility measures are shown graphically in Fig. 1. The equi-energy correction has been applied to the former values and the visibility coefficients computed. It is seen that the original inflection point, in the neighborhood of 540 mμ, has become displaced towards the short waves and the point of maximum visibility is in the green at approximately 510 mμ. The agreement with the scotopic visibility curve as determined by Hecht and Williams[10] is remarkably close, the two curves being practically coincident over the range measured. The standard Illuminating Engineering Society photopic values are shown by the broken line. The visibility measures leave no doubt as to the mechanism functional in the present case. Vision is mediated exclusively by the rods; the cones are completely missing from the picture.

Although the ophthalmological literature of total color blindness suggested the paucity of information to be gathered by a clinical examination of the eye, it was thought wise to supplement the foregoing description by such a procedure. J.M. was examined by Dr. Burton, oculist on the staff of the University of Virginia Hospital,[12] with a view to the detection of any peculiarities of the retina or ocular media. The difficulties of viewing the retina were, of course, increased by reason of the nystagmus and the astigmatism of the subject's eye. However, a few abnormal appearances were clearly discernible through the ophthalmoscope. The optic disk of the right eye showed a considerable pallor extending over the outer (temporal) two-thirds portion. While the left disk showed less, it was clearly paler than the normal. The right eye also showed slight pigmentation patches about two disk diameters inferior and nasal to the disk. In agreement with the reports of Wölfflin and Waardenburg[13] the usual oval reflex of the

[11] Goodwin, Trans. Illum. Eng. Soc. **27**, 828 (1932).

[12] My thanks are due Dr. Edwin Burton for having contributed his time and experience to the thorough examination of this case.—F.A.G.

[13] Cited by Chance, reference 8.

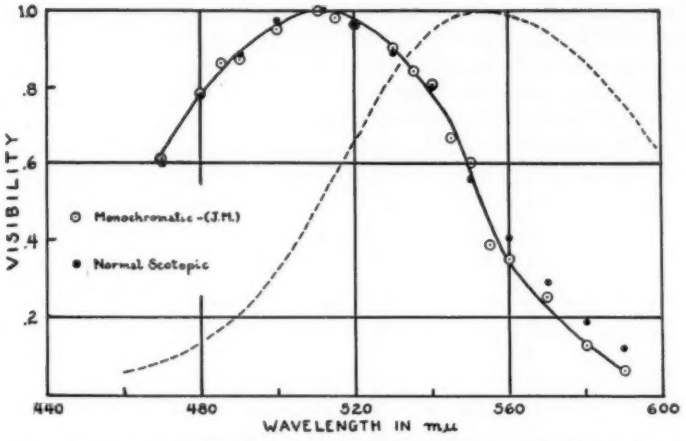

FIG. 1. The smoothed visibility curve for the monochromatic case, J.M., is shown by the continuous line. The values represented by solid dots are those of normal scotopic visibility as determined by Hecht and Williams. For comparative purposes the normal photopic curve (I.E.S. standard) is indicated by the dotted line.

macula was missing, indicating some structural alteration at the center of the retina. Possibly this finding may be correlated with that of Larsen,[14] who found, in the only histological examination yet made of a totally color blind retina, a considerable change in the appearance of the foveal cones. No other abnormal appearances could be detected. Some cases have shown corneal nebulae and albinism of the iris and choroid; neither is present in this case.

Were it necessary to further disprove the claim of Klainguti[15] that total color blindness is a recessive character appearing only when inherited from both parents, the family history of J.M. might be cited. No color defect of any sort has been known in either line. A brother possesses normal color sensitivity and both parents have normal color vision. Among other suggested etiological factors the possibility of consanguinity is vitiated by the present case.

[14] Larsen, Zeits. f. Augenh. **46**, 228 (1921).

[15] Klainguti, Schweiz. Med. Woch. **53**, 910 (1923).

Adoption of By-Laws of the Optical Society of America, Inc.

OFFICIAL ANNOUNCEMENT

The ballots on the adoption of the Proposed By-Laws of the Optical Society of America, Inc., as printed in the *Journal of the Optical Society of America*, Vol. 23, No. 4, pp. 151–155, April, 1933, were counted on May 26, 1933, in accordance with the notice mailed with the ballot.

162 valid ballots were received.

The result of the count showed:

For approval of the Proposed By-Laws	157
Against approval of the Proposed By-Laws	1
Not voting	4
Total	162

The Board of Directors has therefore instructed me to announce that the Proposed By-Laws have been duly adopted and are in force as the By-Laws of the Optical Society of America, Inc.

Signed

L. B. TUCKERMAN, *Secretary*